

# Short Baseline Reactor Experiments elsewhere

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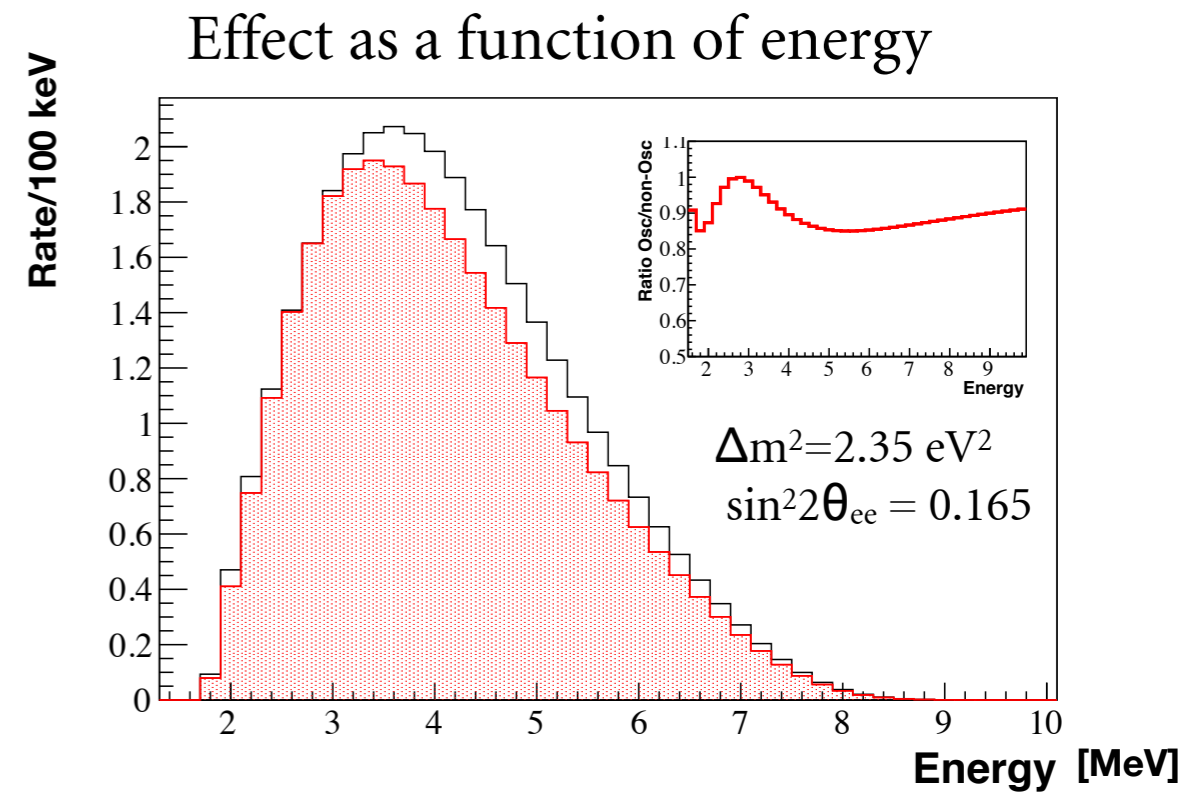
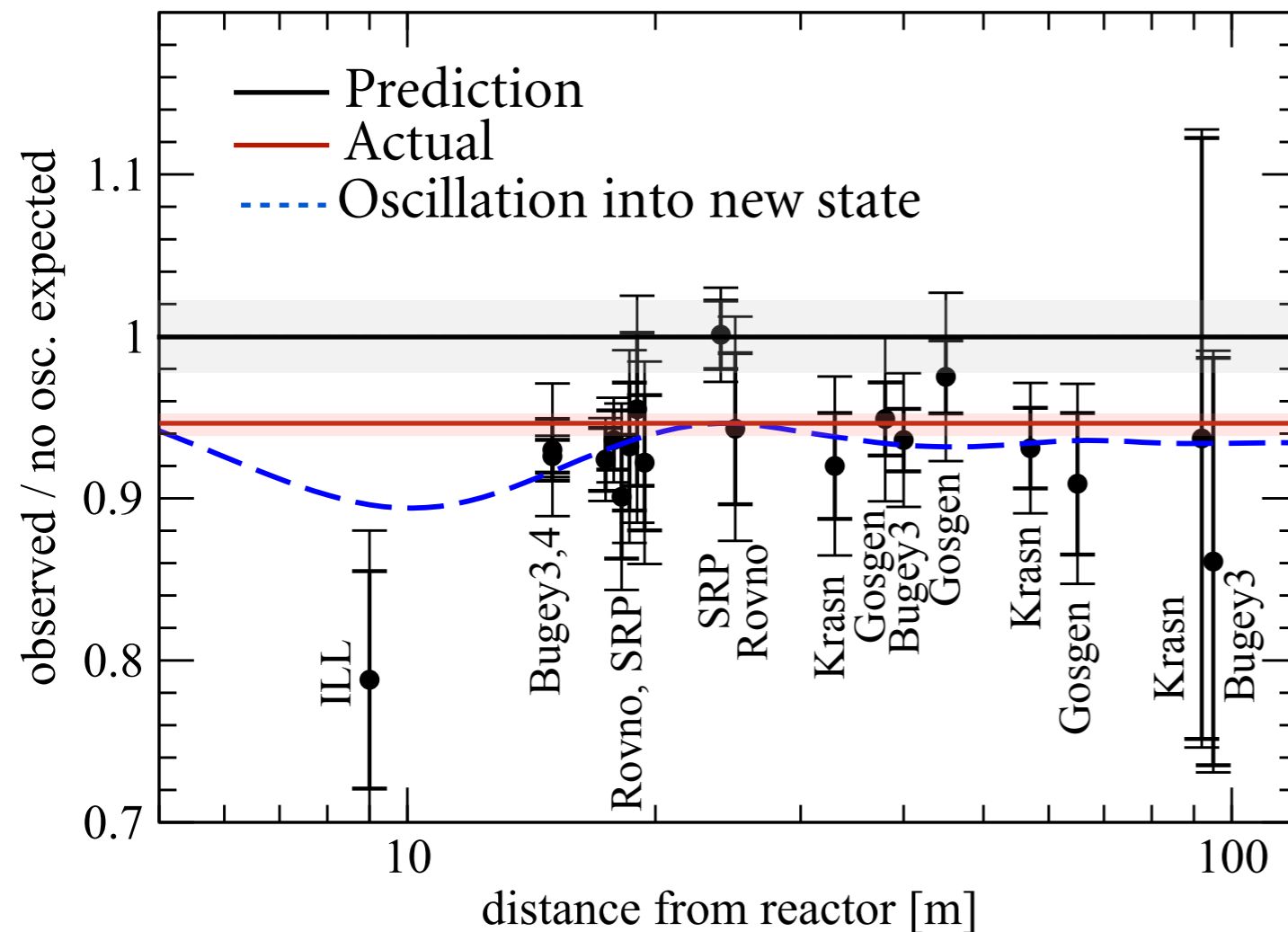
# Aim of this talk

- Give an overview of the current and planned short baseline experiments
- Focus on research reactor experiments

# Reactors

- Research reactors
  - HEU fuel
  - most have compact core
  - good fraction of reactor off data
  - closest distance possible but at cost of high gamma-ray flux
  - constraint on site availability varies
  - Power known to 2-5%
- Power Reactor experiments
  - LEU fuel
  - Extended core limits physics sensitivity
  - reactor off time limited
  - close stand off difficult
  - High neutrino flux
  - Access difficult
  - Power known to 0.5%
- All experiments are limited by systematic effects of at least a few %

# The reactor anomaly



- small effect so aim for % level precision
- close to the surface
- close to reactor cores

# New Reactor experiments

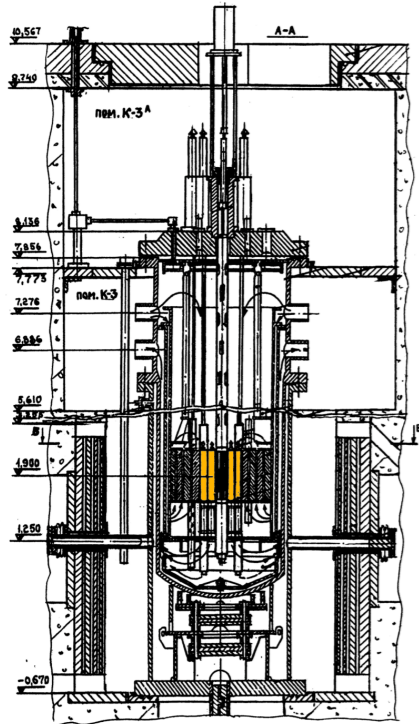


# Current and planned experiments

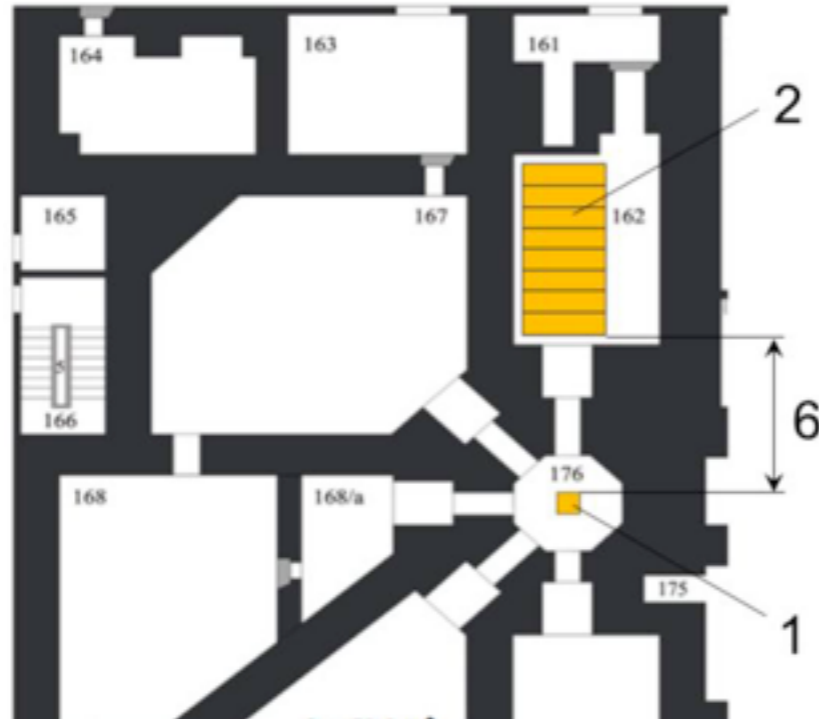
	Tech	Reactor	P [MW]	L (m)	M (tonnes)	status
Neutrino-4 (Ru)	LS+Gd	SM-3	90	6-12	1.5	first run
Nucifer (Fr)	LS+Gd	OSIRIS	70	7	0.8	running
SoLid (UK/B/Fr)	PVT + <sup>6</sup> LiF:ZnS	SCK•CEN BR2	45-80	5.5-11	1.44/2.88	enter 1st run
DANSS (Ru)	PS + Gd	KNPP	3000	9.7-12.2	0.9	prototype run construction
STEREO (Fr/Ge)	LS+Gd	ILL-HFR	57	8.9-12	1.75	construction
Korean project	LS + Gd/ <sup>6</sup> Li	Hanaro Hanbit	30 2800	6-?	~1	R&D prototype

# Neutrino-4

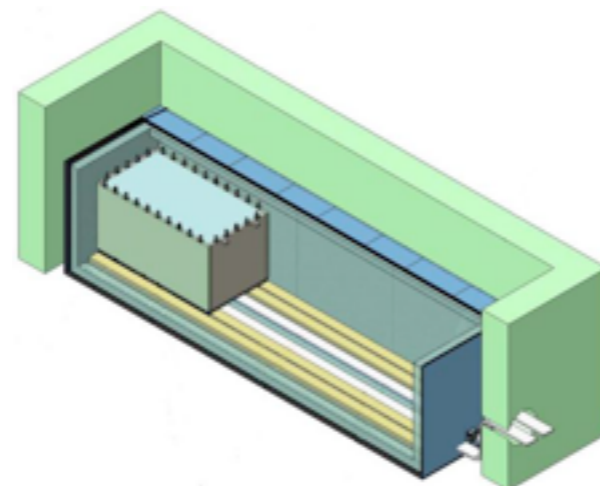
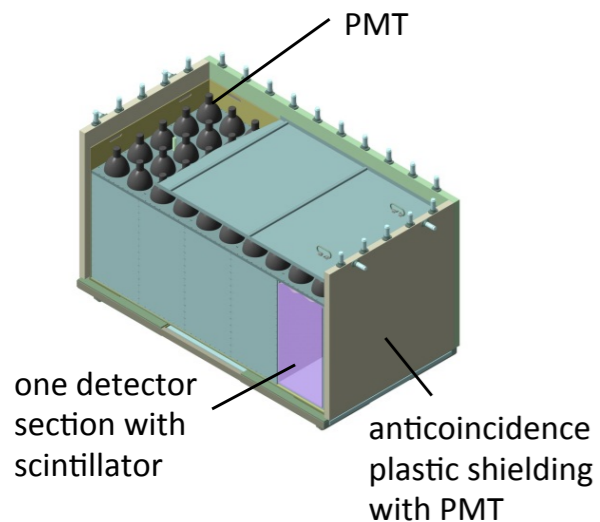
## SM-3 Reactor Dimitrograd, Russia



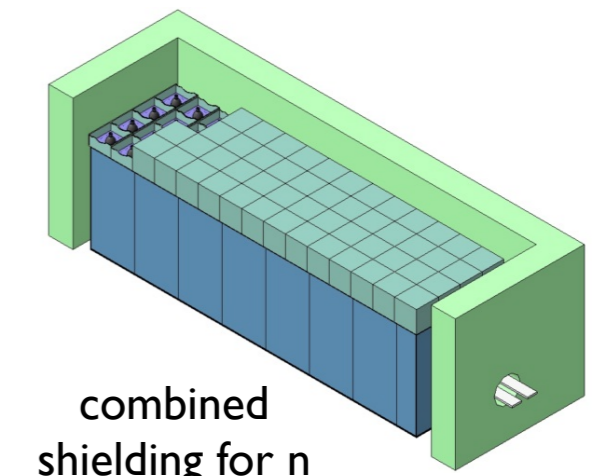
Core size  
35 x 40 x 40 cm<sup>3</sup>



- Dedicated site at SM-3
- Probe oscillation effect with distance ( $1/R^2$ )
- homogenous detector design, 1.5 tonnes
- Challenging background conditions
  - 60 tonnes of shielding
- First run with 1 detector unit (400L)



moving platform on  
rails 6m - 12m



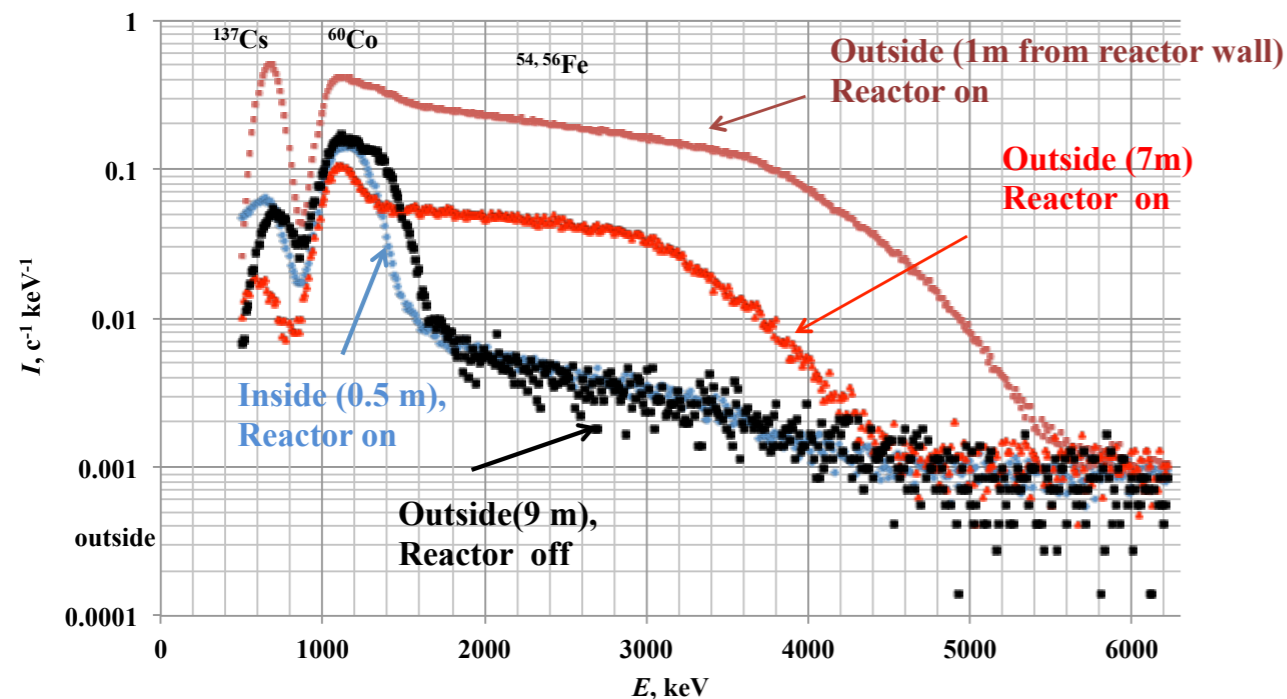
combined  
shielding for n  
and gamma-rays

# Background studies

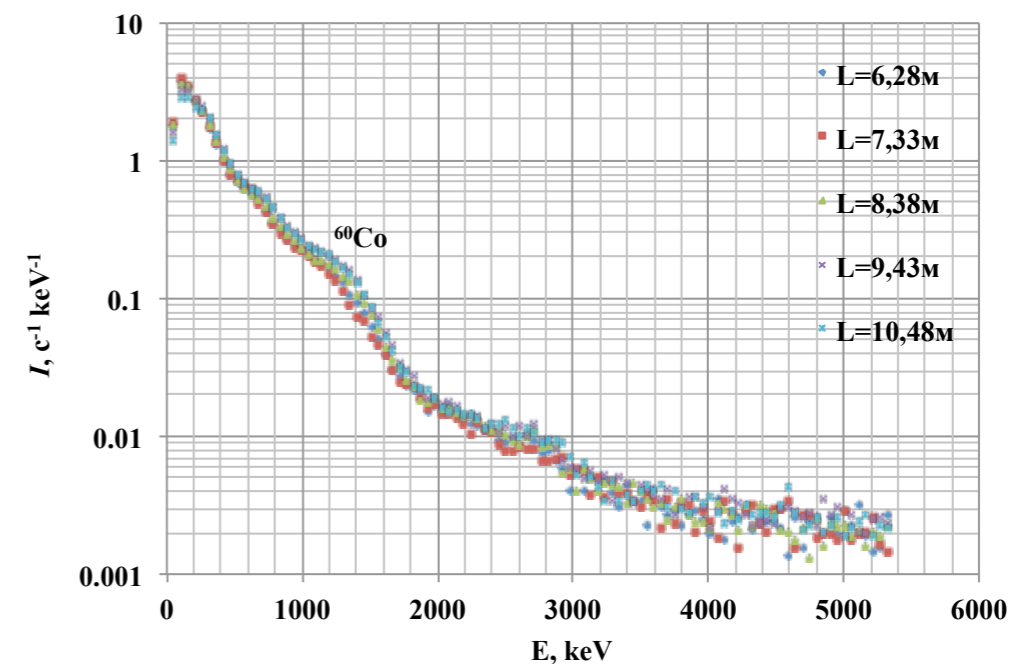
- Extensive survey of backgrounds vs distance
- found variations up to 14%



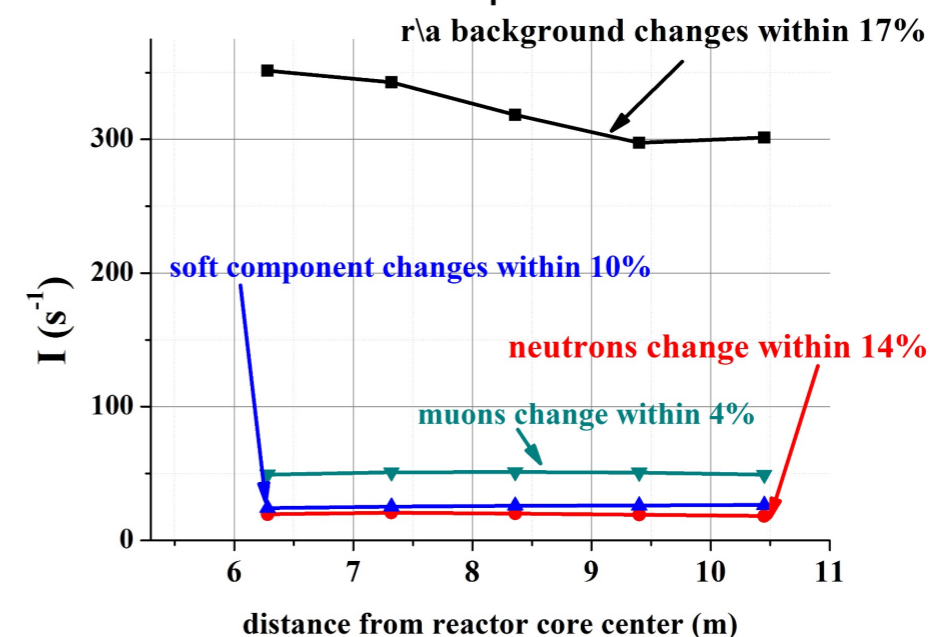
NaI detector measurements + calibration data



Gamma-rays at various distance on axis

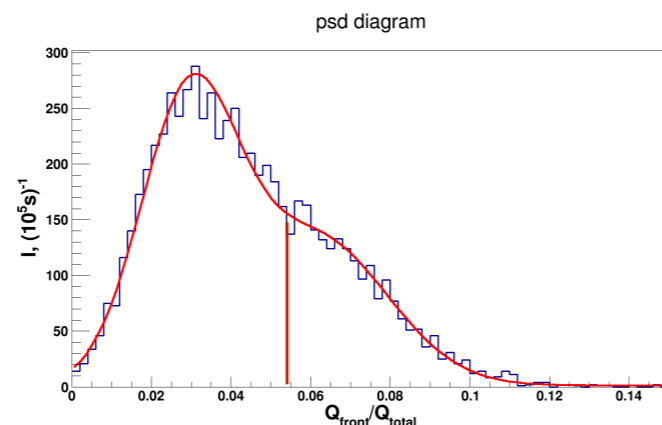


Cosmics spectrum

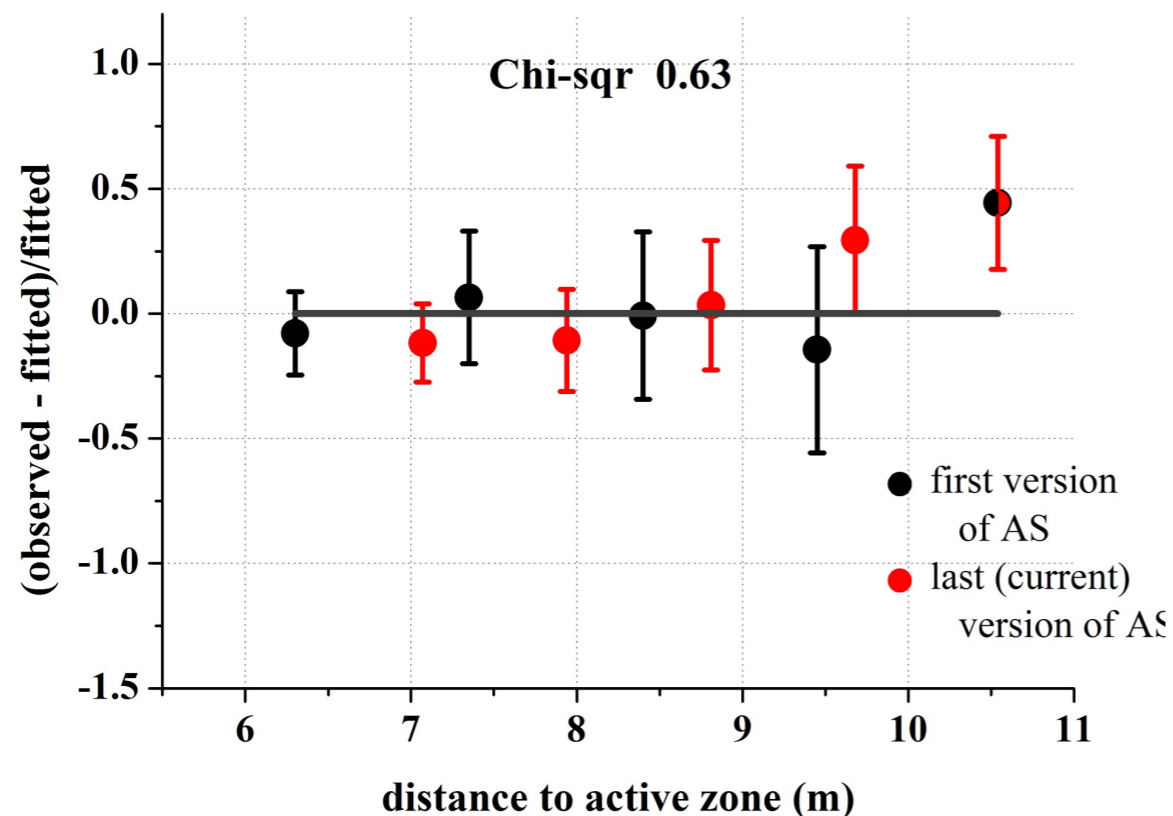


<i>Thermal neutrons flux</i> ( $s^{-1}cm^{-2}$ )	<i>Fast neutrons flux</i> ( $s^{-1}cm^{-2}$ )	<i>Place of measurment</i>
$(0.34 \pm 0.07) 10^{-5}$	$(4.4 \pm 0.5) 10^{-5}$	Inside
$(17.7 \pm 1.2) 10^{-5}$	$(69 \pm 2) 10^{-5}$	On the top
<b>Shielding factor</b> $K_{th} = 53$	<b>Shielding factor</b> $K_{fast} = 16$	

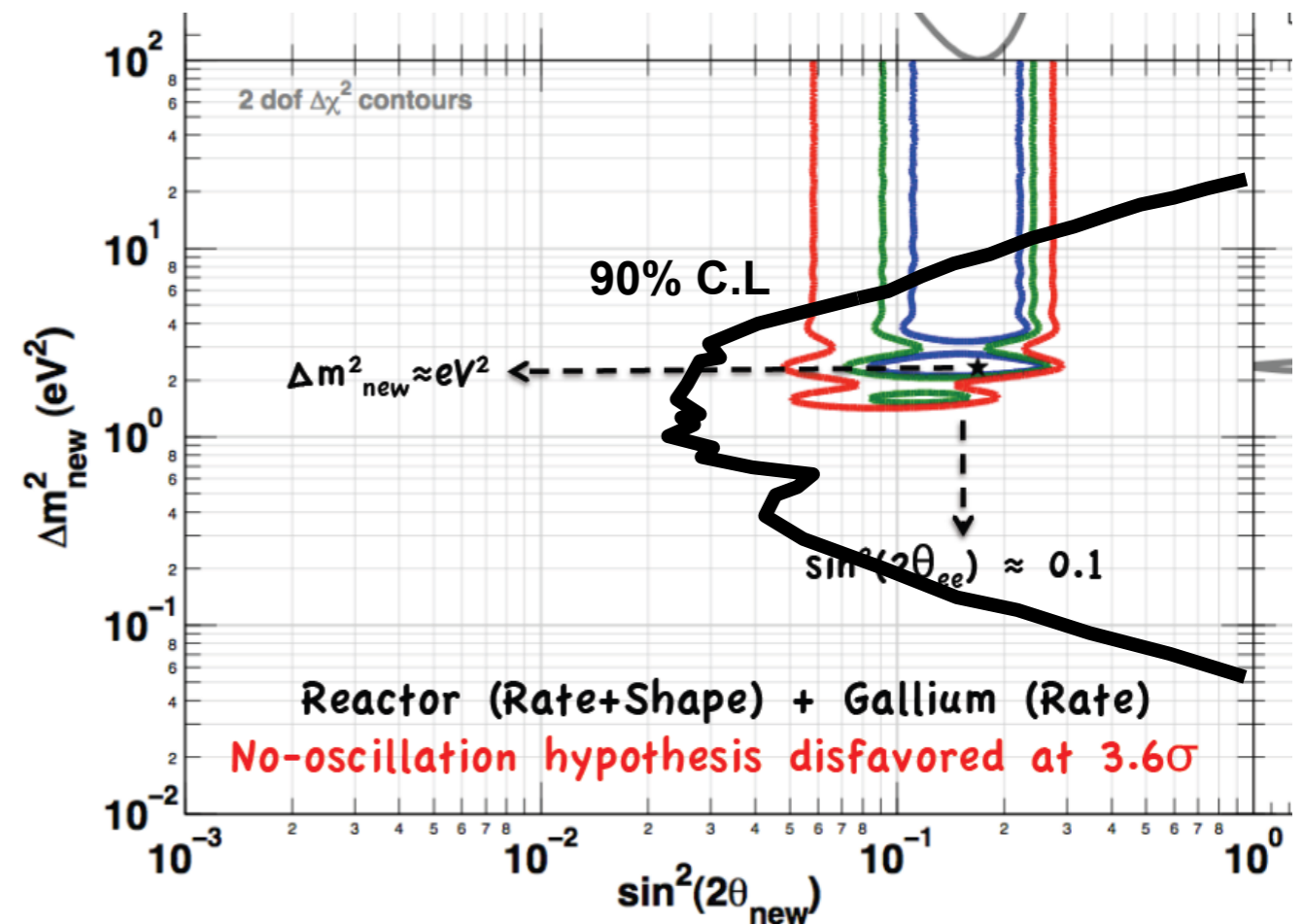
# 400L first results & sensitivity



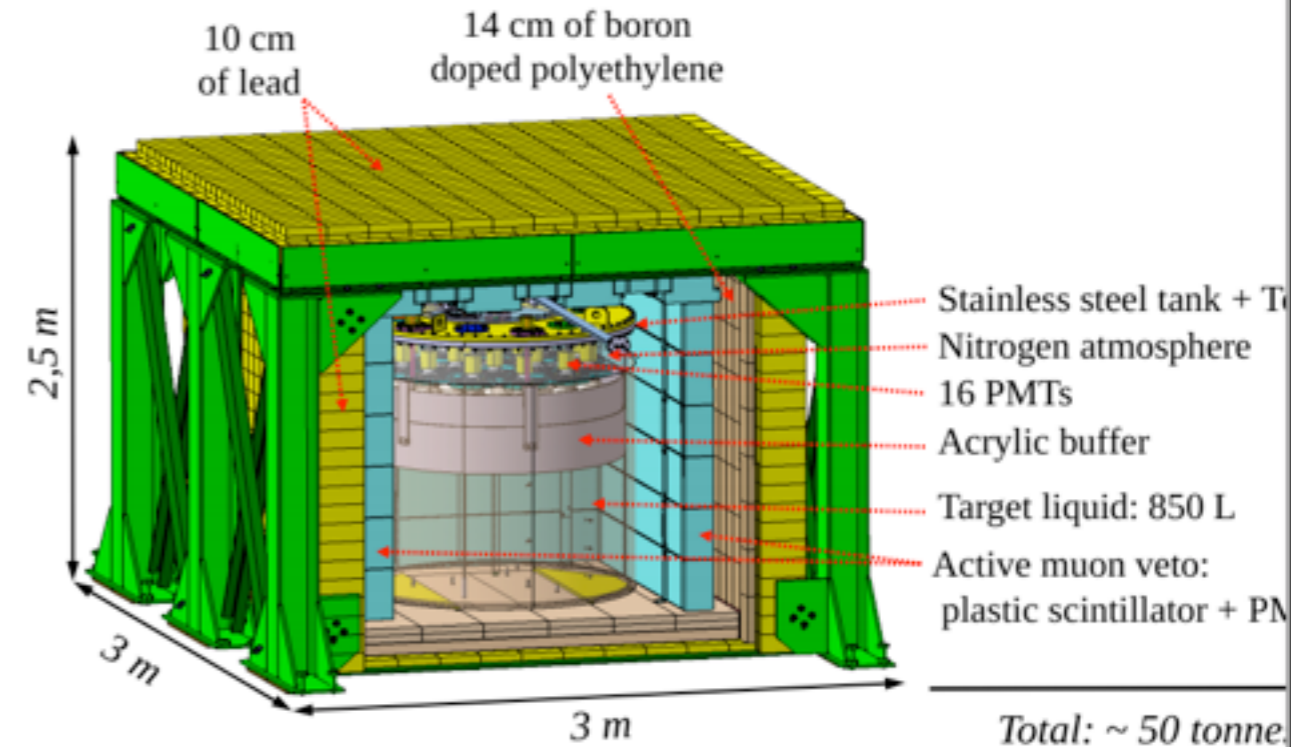
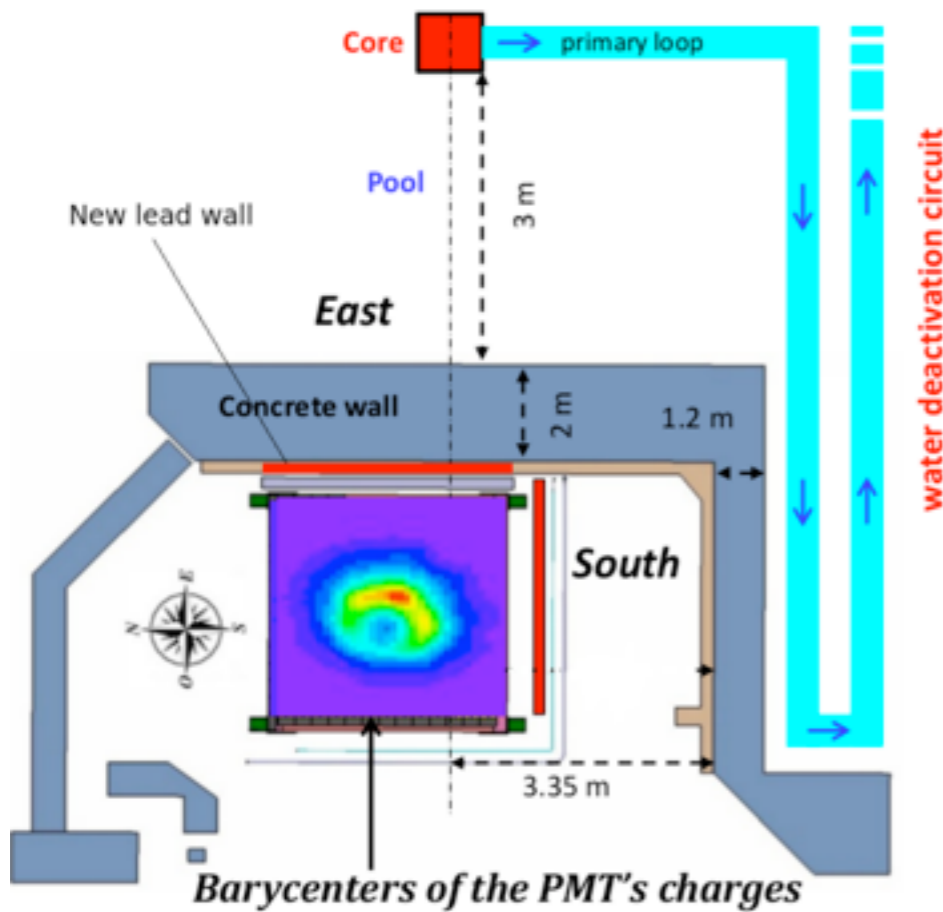
start 3 MeV, stop 3 MeV



- first measurement in  $1/R^2$
- IBD efficiency 15%,  $\sim 130$  candidates/day
- next phase:
  - full scale system
  - active shielding around passive shielding

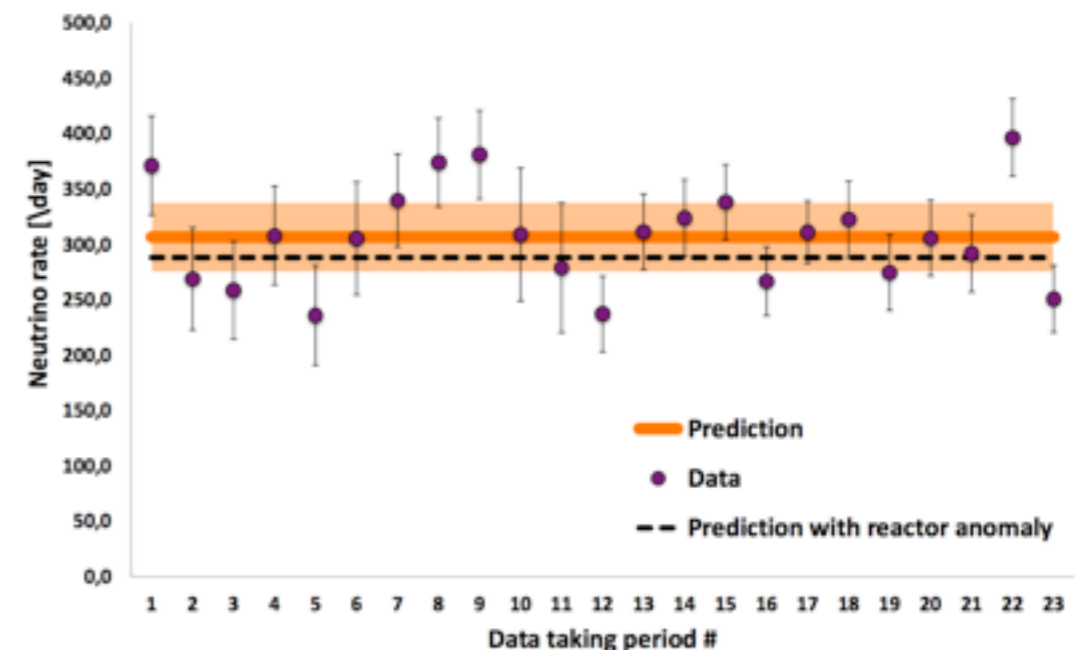


# Nucifer



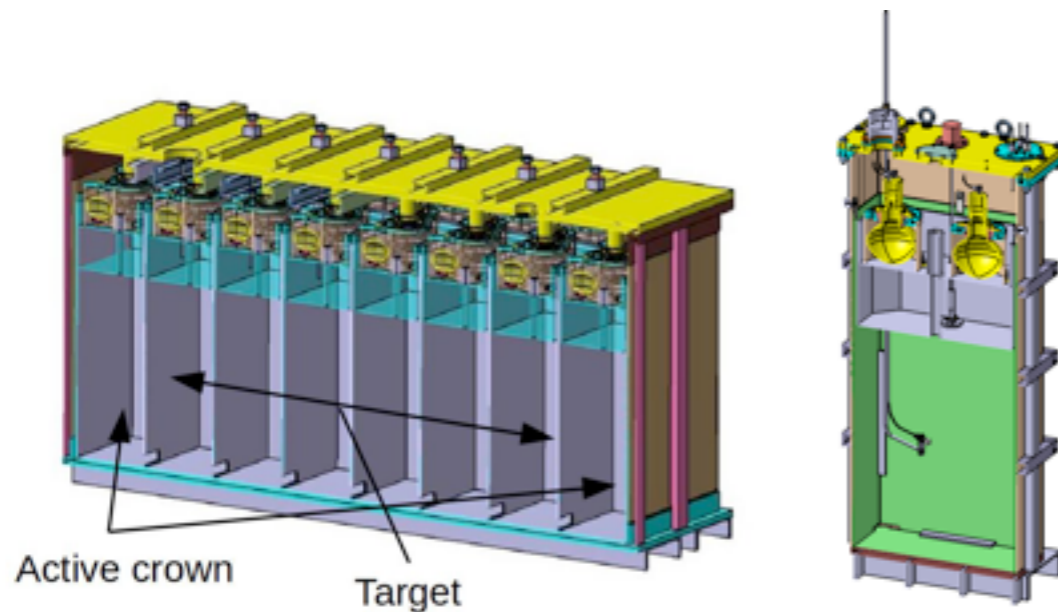
	Accidental rate	Correlated rate
Reactor OFF	$(75 \pm 1) / \text{day}$	$(1063 \pm 10) / \text{day}$
Reactor ON	$(3793 \pm 1) / \text{day}$	$(1384 \pm 15) / \text{day}$

Nucifer @ Osiris

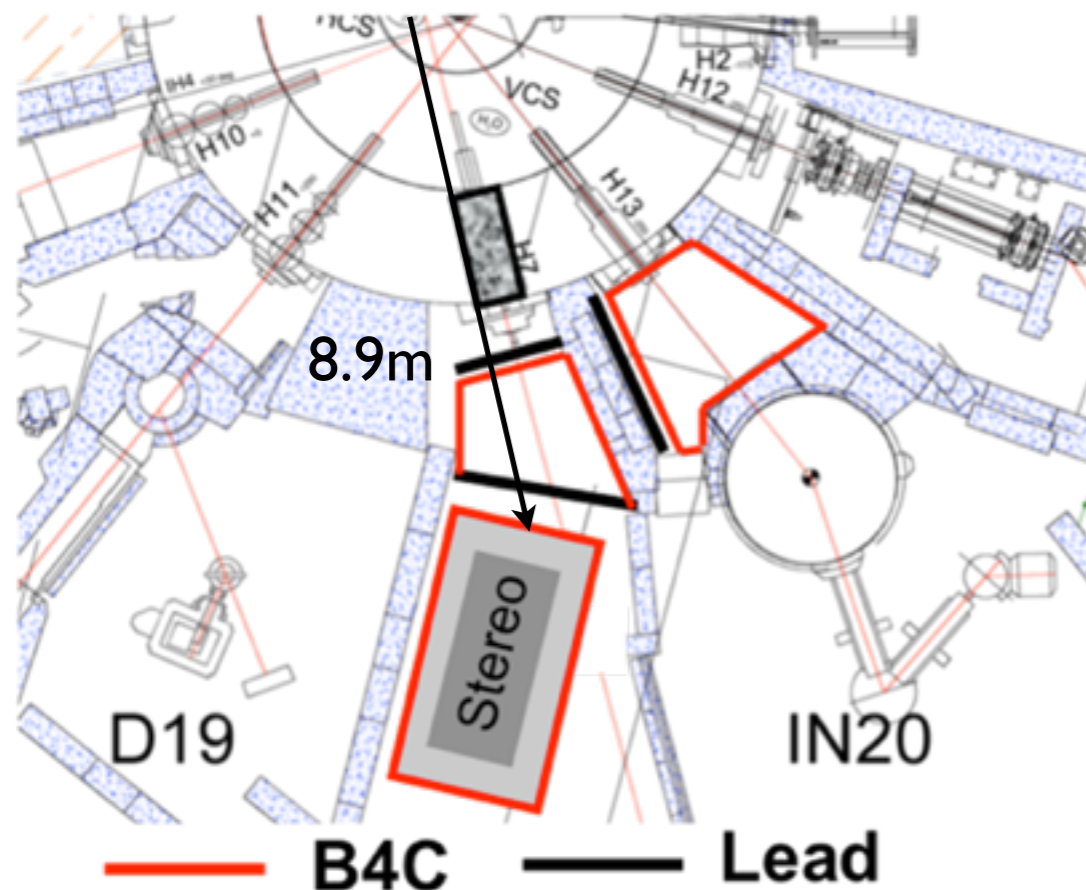


- project oriented to reactor monitoring
- homogenous detector
- 105 days, ~300 candidates /day
- Very challenging gamma-ray background
  - S:B ~1/12 accidentals S:B ~ 1/3 correlated
- Backgrounds dominates the uncertainties

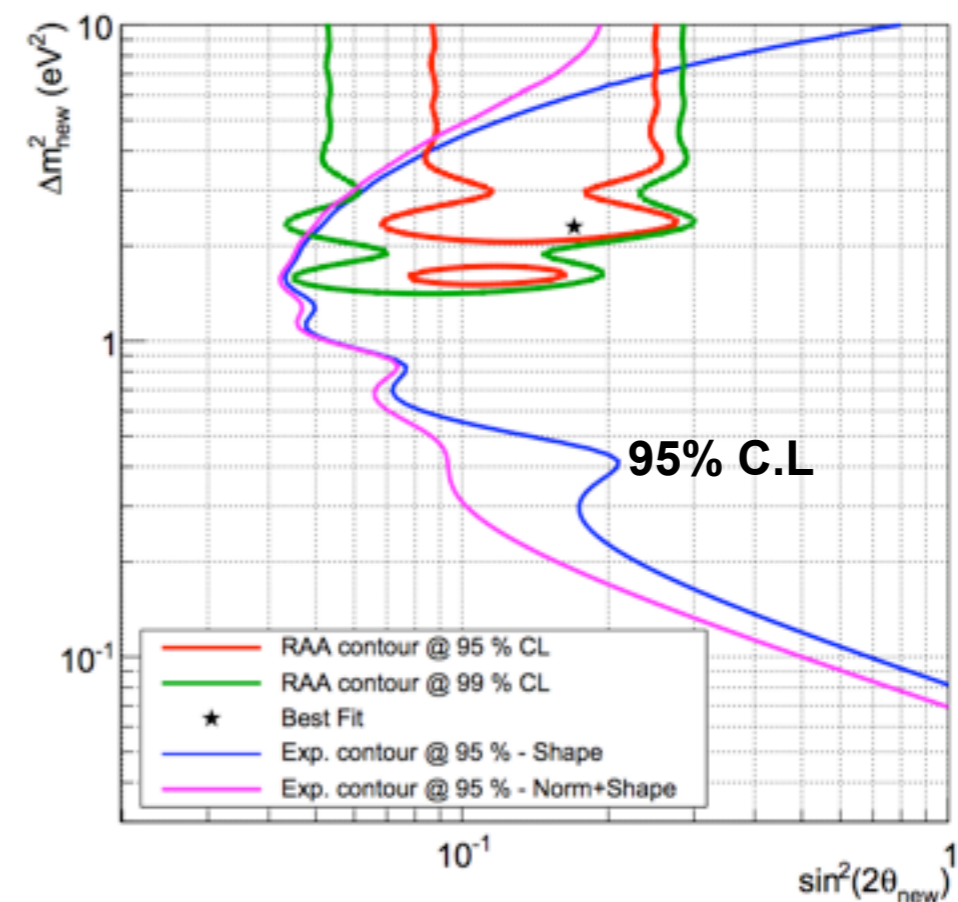
# STEREO

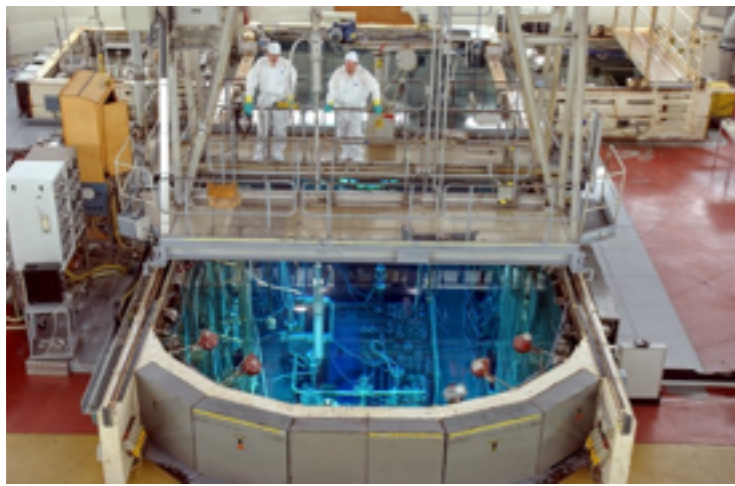


40x90x90 cm<sup>3</sup> cell size

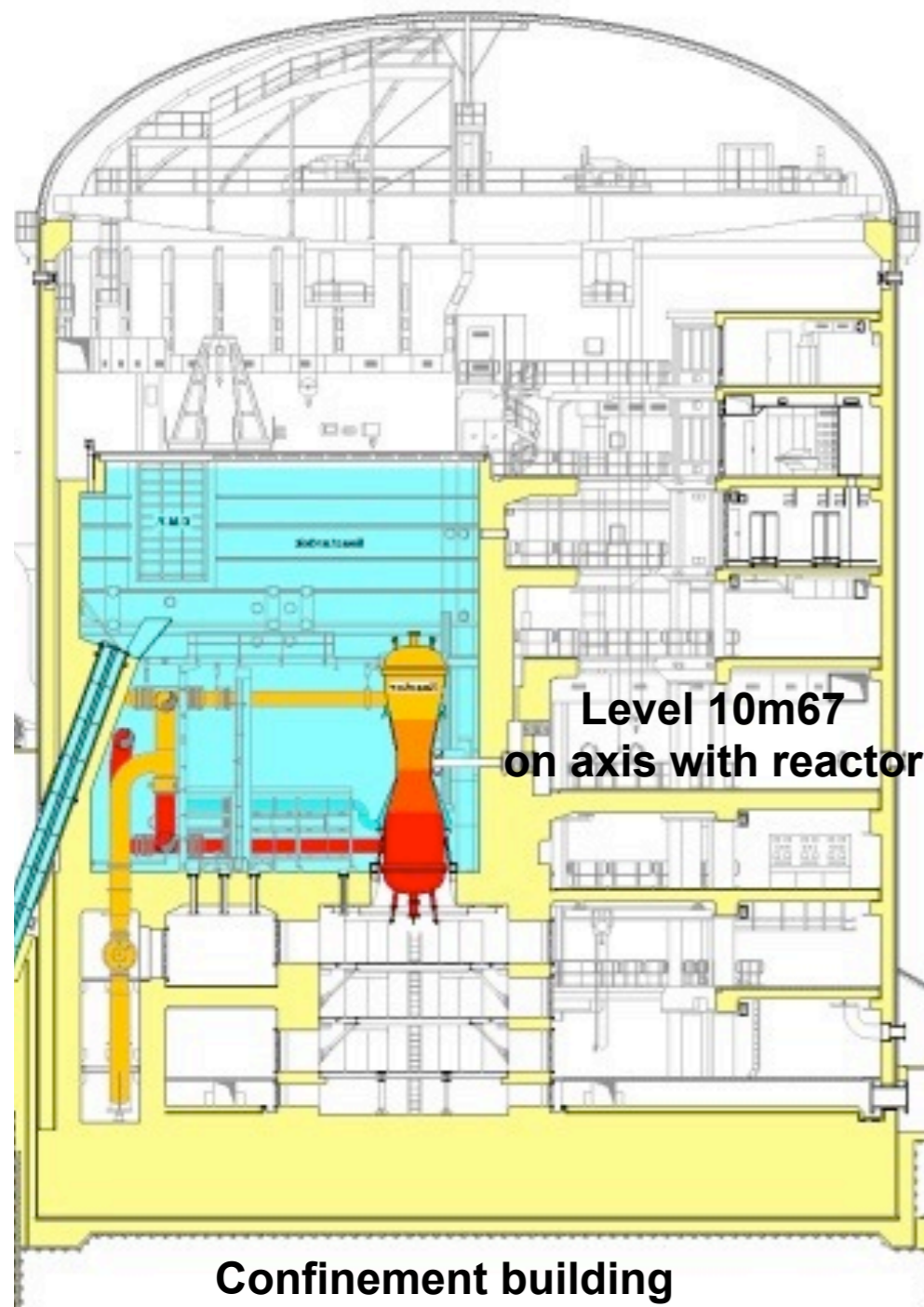
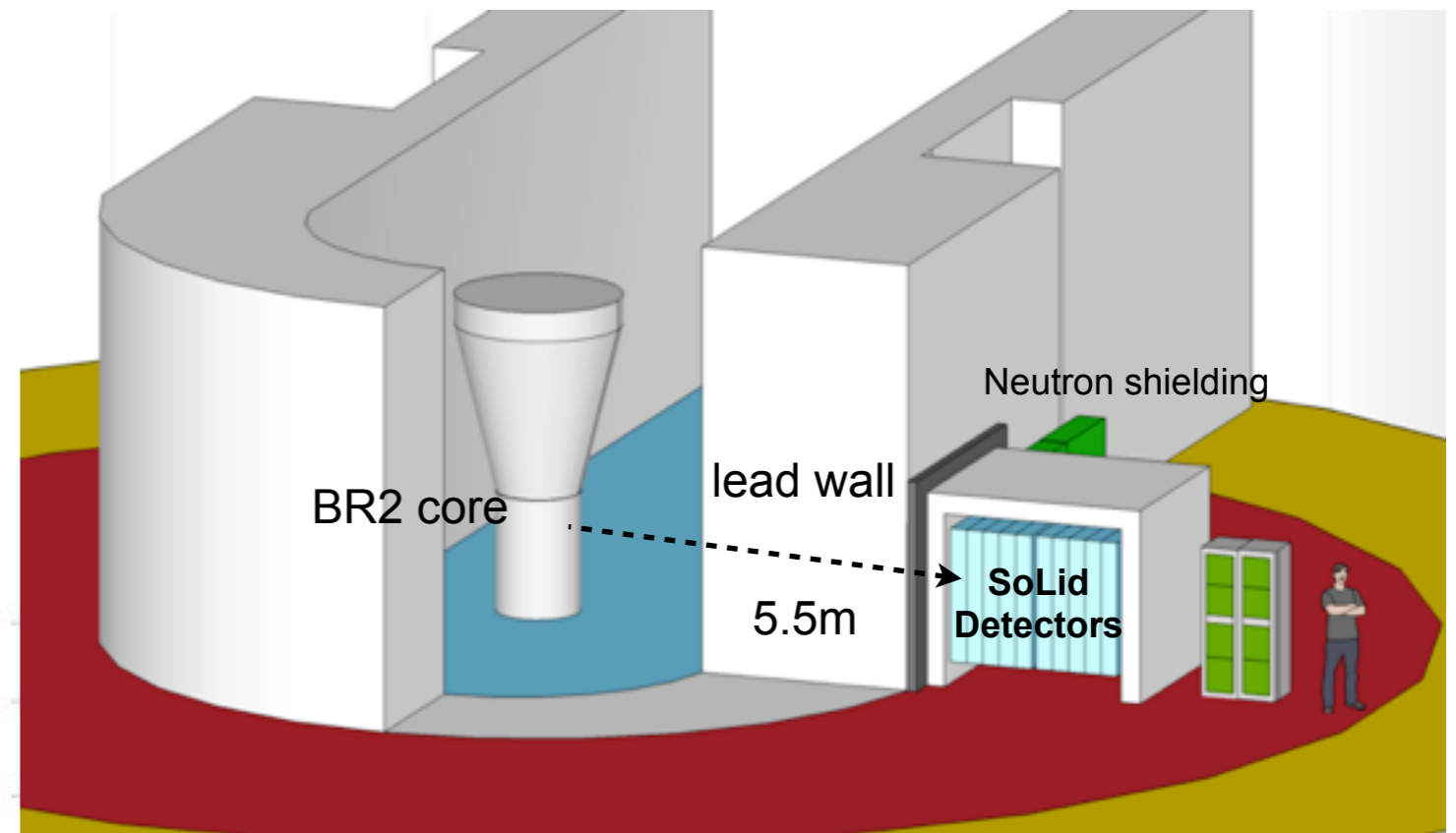


- LS +Gd with coarse segmentation
- good overburden
- but around other neutron experiments
- challenging background conditions
  - heavy shielding
- Prototype built and optical studies started
- deployment planed for end of 2015

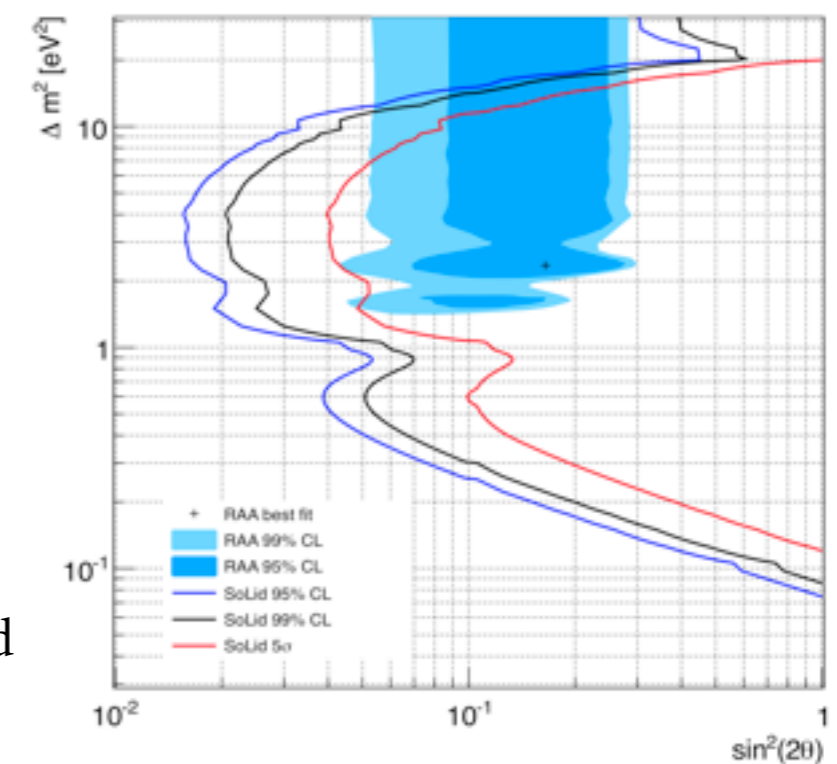




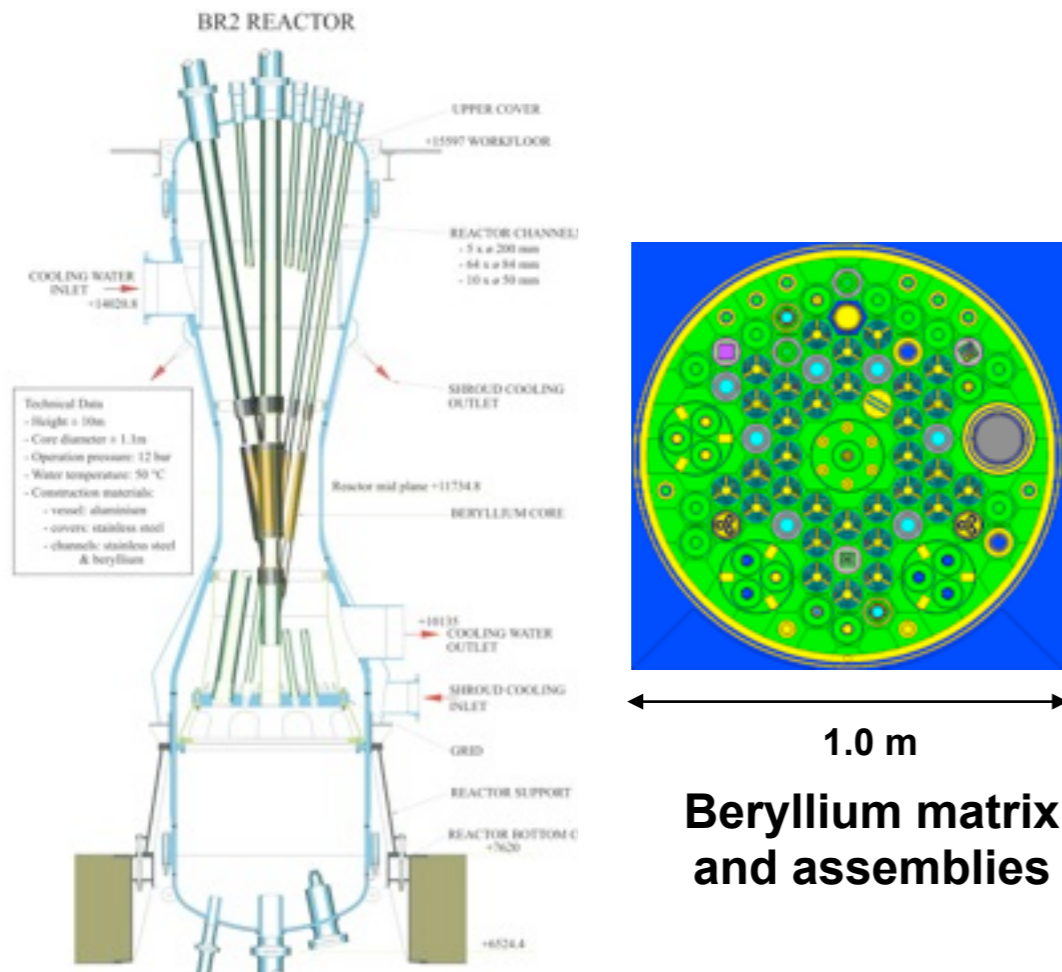
# SoLid



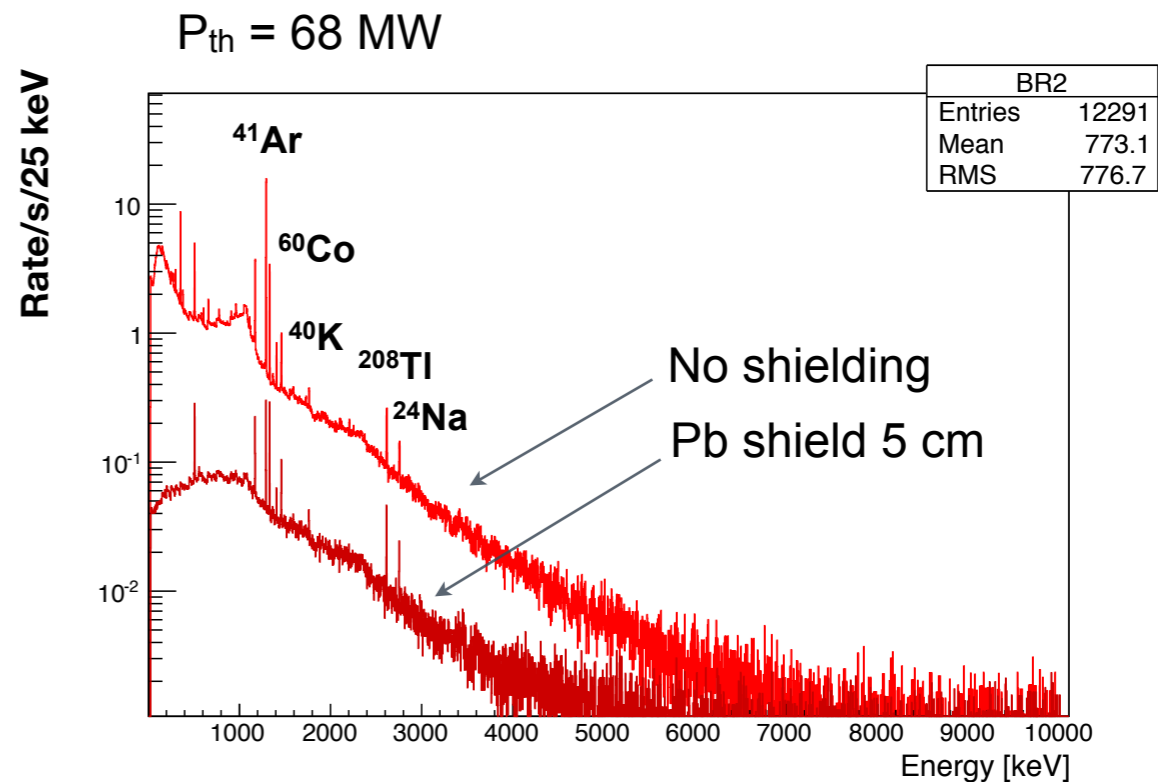
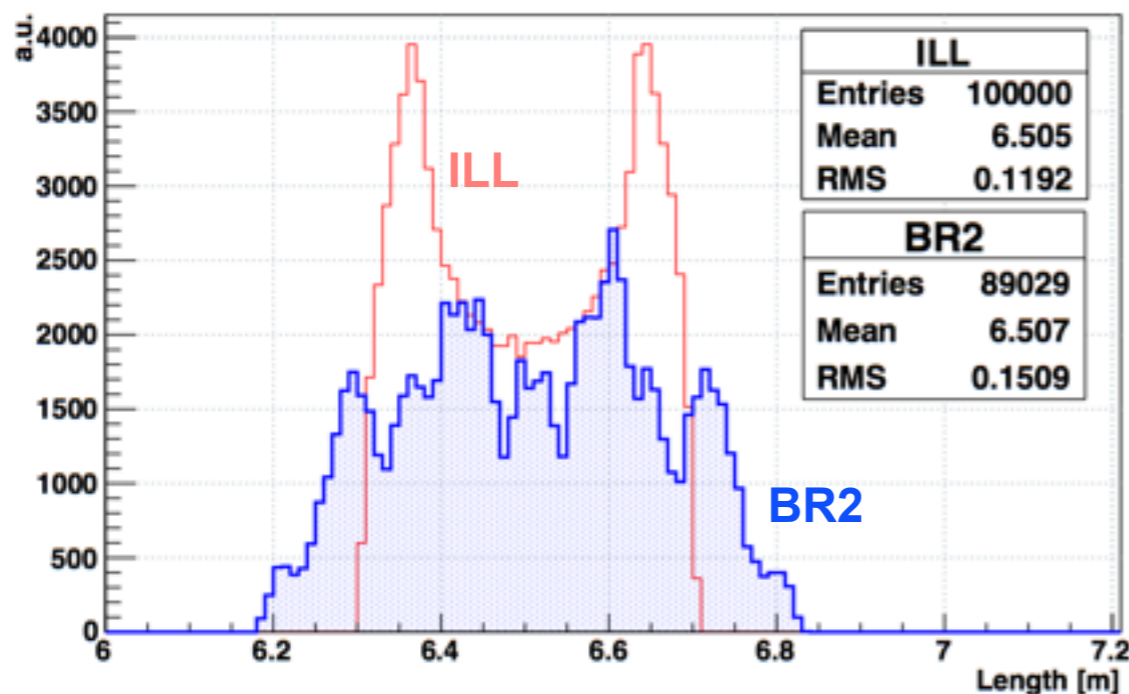
- SCK•CEN BR2 MTR reactor
- beam ports unused
- 2.88 tonnes highly segmented detector
- reconfigurable baseline
- 10 mwe overburden
- main phase planed for mid 2016



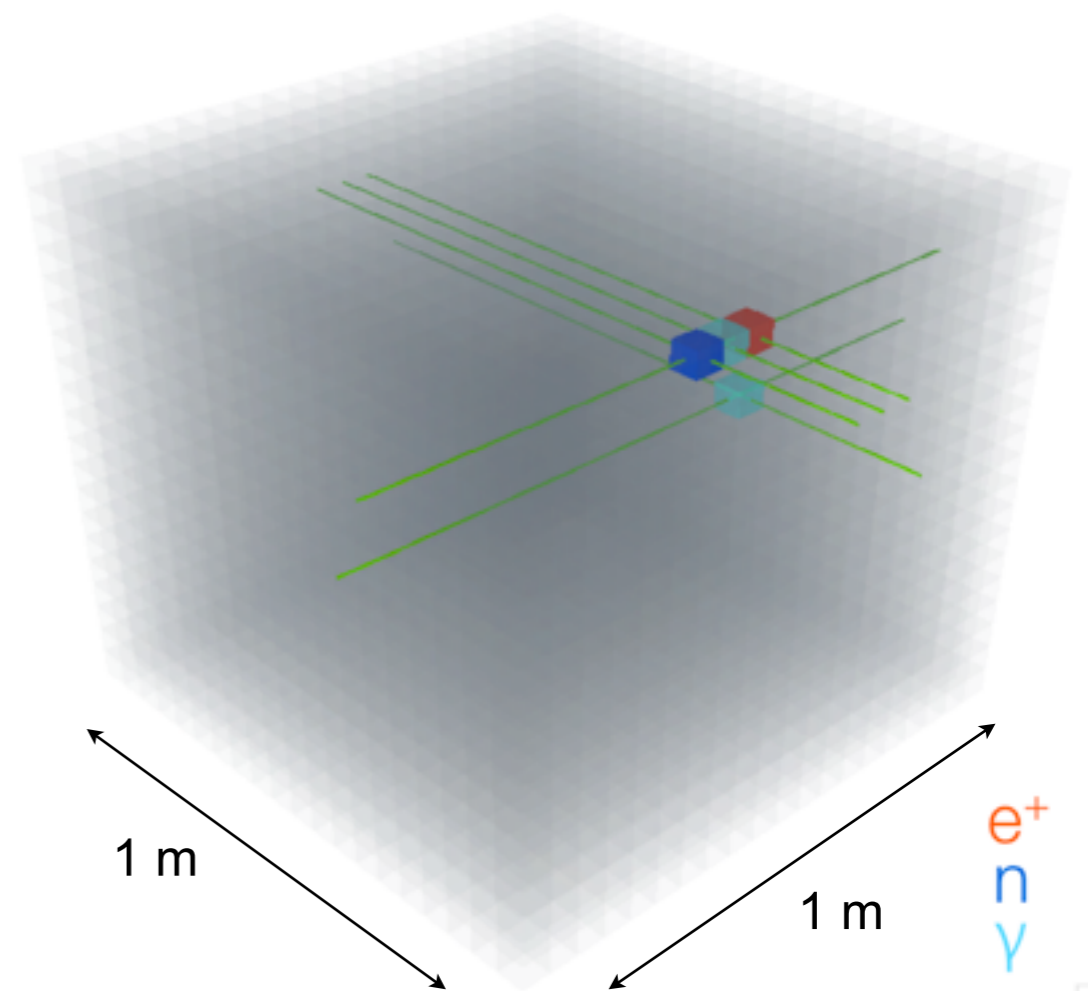
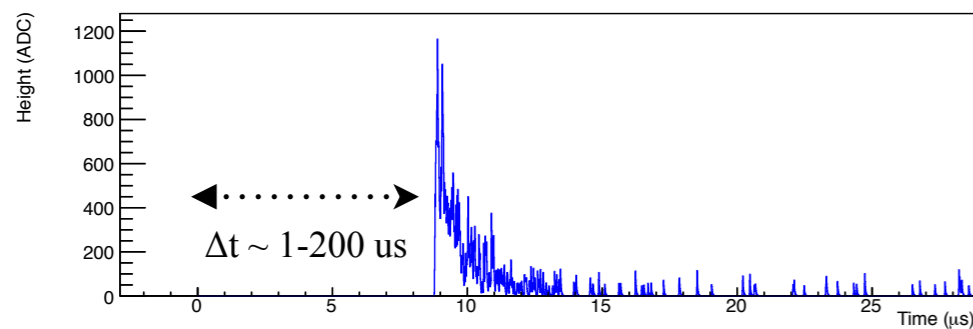
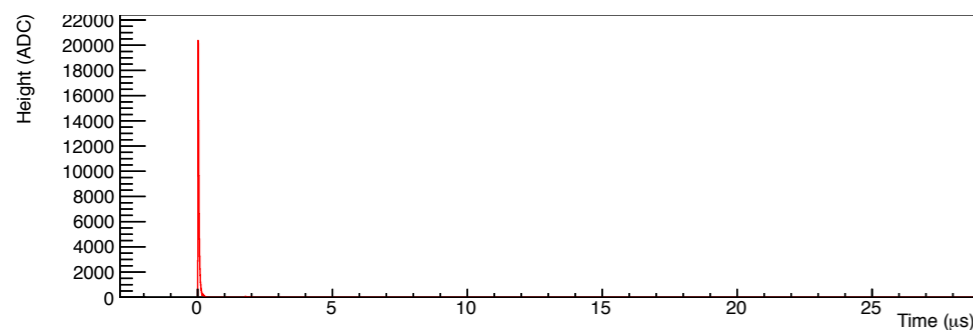
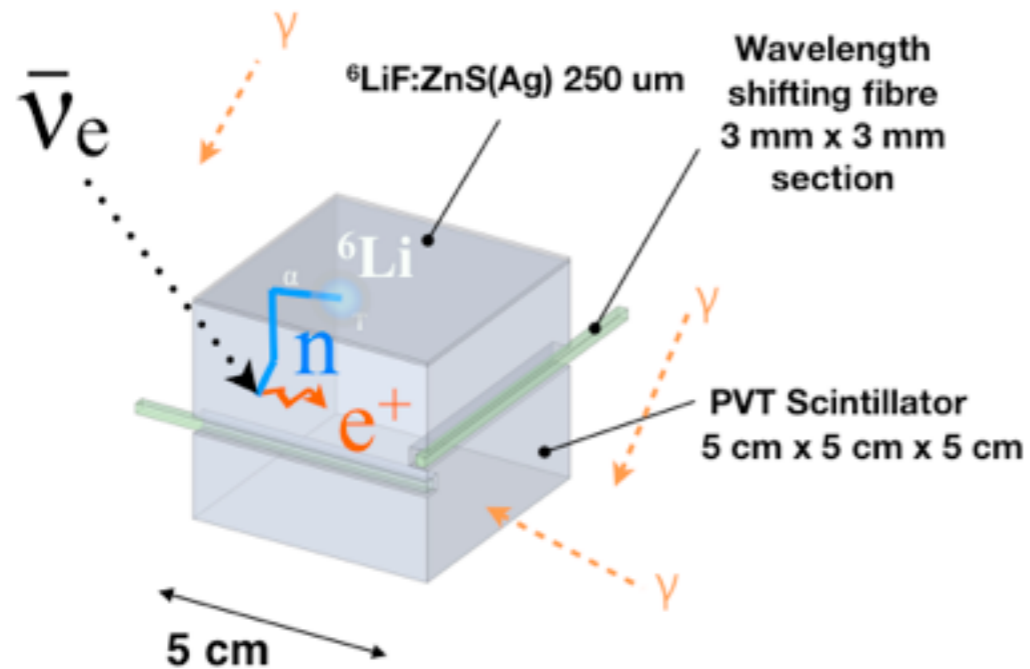
# BR2 reactor



- MTR reactor
- in core irradiation facility
- Operates in 45-80 MW range
- 6 cycles per year
- effective core size matches ILL size
- Remarkably low rate and energy of gamma-rays
- higher S:B ratio possible
- no evidence of reactor ON neutrons



# SoLid concept

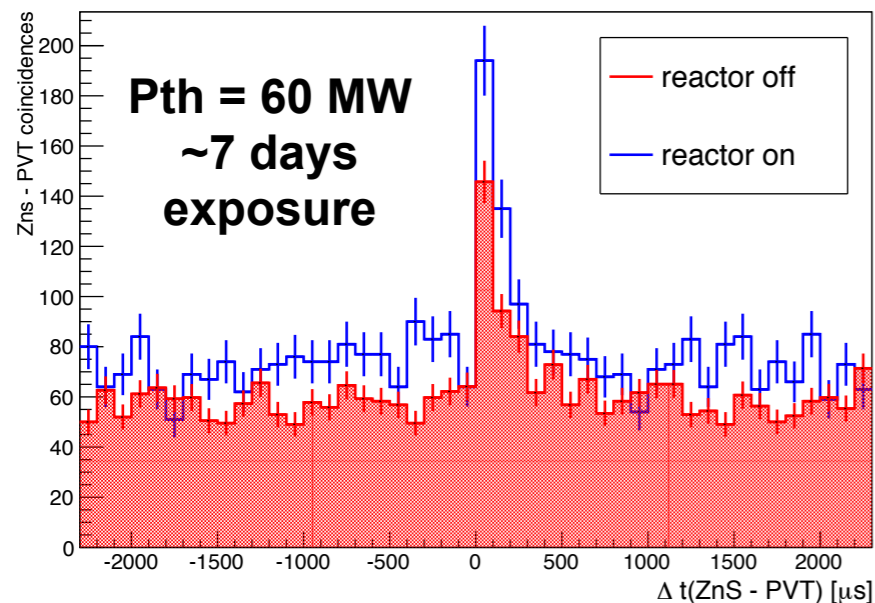
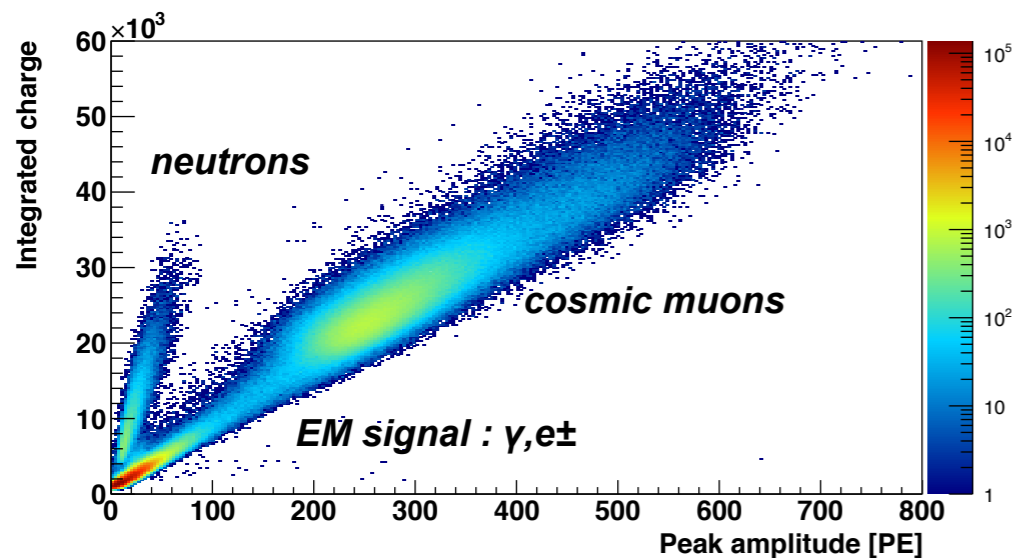
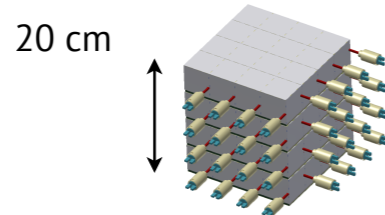


- Neutron / gamma-ray discrimination from pulse
- distinctive response for prompt and delayed signal
- neutron used to trigger event read out
- Voxelisation of target volume
- neutron captured in neighboring cube increasing localisation of IBD event
- Eres  $\sim 17\%$  and  $< 5\text{cm}$  position resolution

# Status

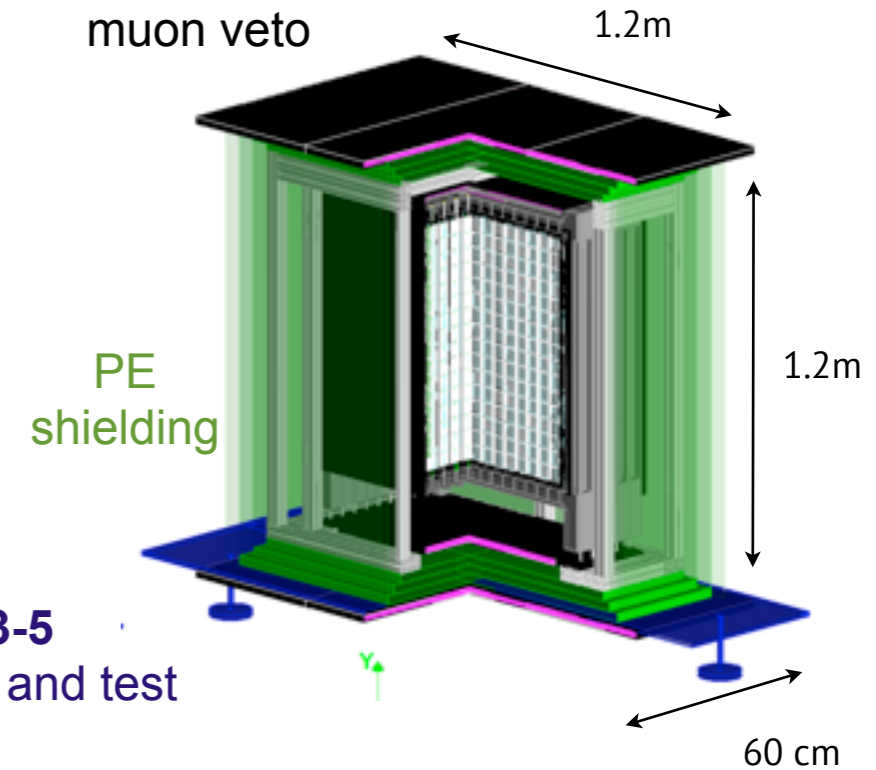
2013 - 2014

- prototype  
NEMENIX **8kg**  
64 voxels, 32 chan.



2014 - 2015

- SoLid Module 1 (SM1)  
**288kg**  
**9 Detector planes**  
2304 voxels, 288 chan.



- Large scale system **TRL 3-5**
1. demonstrate scalability and test production schedule
  2. demonstrate segmentation capability
  3. do some physics ?

- NEMENIX taking data
- SM1 under commissioning
- aim to take data this month before reactor shut down



# Summary

- The job is not done !
- several effort in Europe and elsewhere to address the reactor anomaly
  - but a small number of research reactors with very different environments
  - requires current generation experiment precision but in much more challenging environment
  - A lot of expertise needed in very different areas
- improving on the knowledge of the reactor spectrum is a requirement
  - again not all experiment can do it
- US has research reactors and extensive experience in this area
- exploring potential collaboration between Europe and US could change substantially the state of the competition